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TECHNOLOGY TRANSFER PROGRAM (TTP)

FINAL REPORT

PLANNING & PRODUCTION CONTROL

0028

PLANNING & PRODUCTION CONTROL EXECUTIVE SUMMARY

Prepared by:

Livingston Shipbuilding Company
in conjunction with:
IHI Marine Technology, Inc.

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PREFACE

This document is a summary of a report on Planning & Production Control resulting from the Shipbuilding Technology Transfer Program performed by Livingston Shipbuilding Company under a cost-sharing contract with the U.S. Maritime Administration.

This summary provides a condensation of the findings and conclusions of Levingston's study of the practices currently in use in the shipyards of Ishikawajima-Harima Heavy Industries Co., Ltd., (IHI), of Japan. Livingston gratefully acknowledges the generous assistance of the IHI consulting personnel and of all the IHI personnel in Japan who made this study possible.

For details concerning the Technology Transfer Program or of the information contained herein, please refer to the full Final Report on this subject.

EXECUTIVE SUMMARY

THE IHI PRODUCTION SYSTEM

The IHI shipyard production system is a composite of facilities, personnel and material which achieves, through the careful integration of these elements, an extremely high rate of productivity. The composite system relies heavily on the thorough planning and scheduling accomplished prior to the start of steel fabrication and which is continually refined throughout a production run of ships.

The IHI production system has been perfected over a number of years to a point where an established routine of design-planning-production-control is now in effect for the manufacture of any type of ship. This routine varies only slightly from yard to yard and the basic principles of this methodology are almost never modified.

As in most shipyards the major production activities are divided into hull construction and outfitting. Each of these activities is organized and executed by a separate “Workshop”. Hull construction encompasses all steel fabrication, sub-assembly, assembly and erection of the final hull units. Outfitting is planned and organized to correspond with the hull construction work so that appropriate outfitting of components and sub-assemblies is accomplished at the best time during manufacture of the steel unit assemblies.

The manufacture of steel parts and pieces, the assembly of these components into progressively larger and more complex units, and ultimately the construction of these units into the ship itself, is the function of the Hull Construction Workshop. In IHI the process of hull construction utilizes designated material flow routes called "process lanes" for the processing of all material. "Process Lanes" extend through several different physical areas either within shops or assembly areas in a series of operations referred to as "Sub-stages". These "Sub-stages" are part of a larger process step called a "stage". Figure 1-1 illustrates this organization of production into the various process lanes, sub-stages and stages.

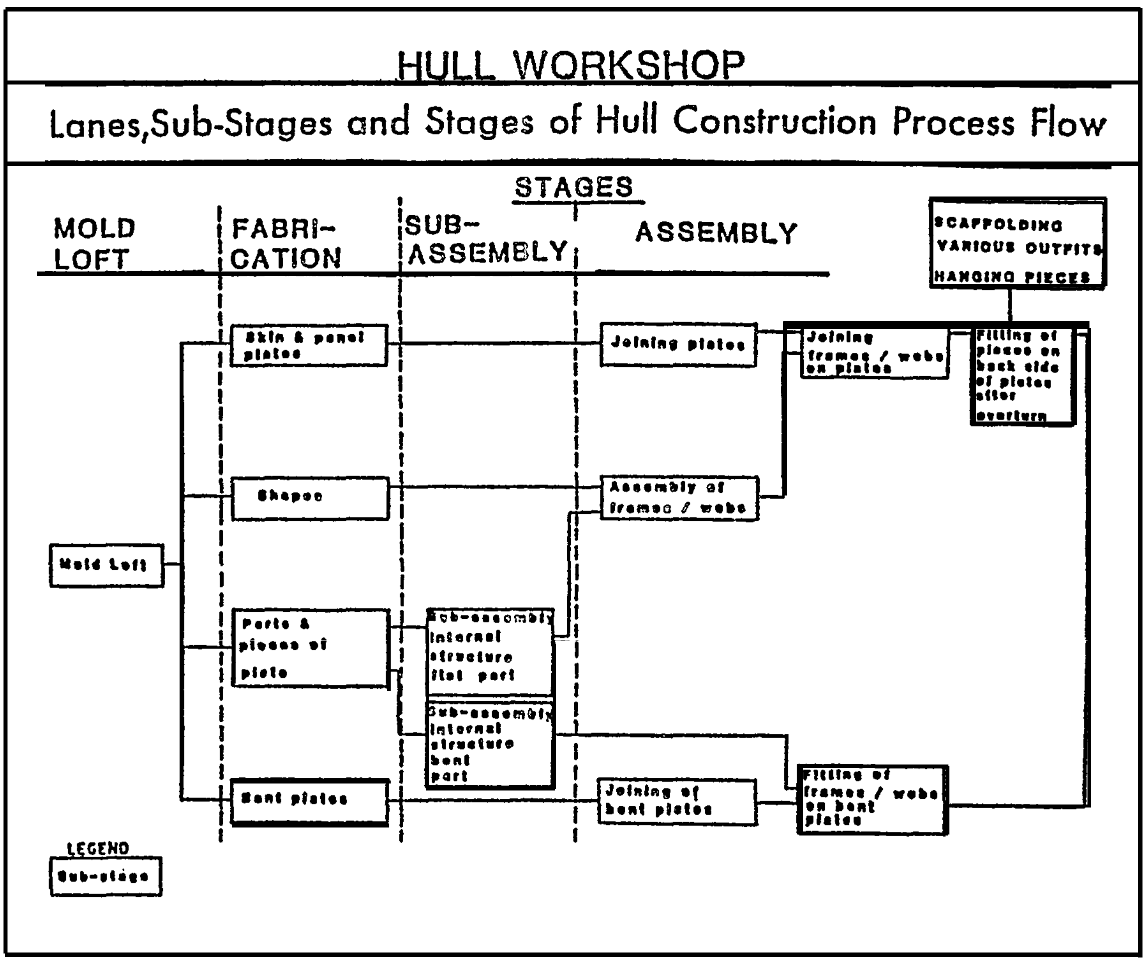


FIGURE 1-1

ORGANIZATION FOR PRODUCTION

This type of production system aligns the physical areas of the overall facility into several material flow paths which begin with the fabrication of detail parts and pieces, the subsequent sub-assembly of these pieces into one or several minor assemblies which will then be integrated into a unit. For example, in the fabrication shops the steel plates are sized, marked, cut and bent in different process lanes according to their eventual usage in flat panel or curved units. These piece parts are routed to appropriate sub-assembly or assembly areas for use in the construction of the two different types of units. The typical flow is thus from the fabrication of panels or cut pieces to sub-assembly to assembly of either flat-panel or curved units. The completed units will subsequently be moved to a unit buffer storage area or to the platen area adjacent to the building basin. Approximately 30 to 60 percent of all ship units will be completed prior to the start of ship erection.

The second major activity of the production system is outfitting. IHI has developed its planning and production system so that as much outfitting as possible can be achieved during the build-up of the steel unit assemblies. This “pre-outfitting” has provided the IHI yards with substantial improvements in productivity over the past decade.

Essentially, outfitting is considered in three distinct stages: on-unit, on-block and on-board. On-unit outfitting is the sub-assembly of outfitting components (such as piping) into a composite for eventual installation as a sub-assembly onto a steel structure. On-block (unit) outfitting is that performed while the assembly of the steel components is being accomplished in an assembly area. At the appropriate time in the build-up of a steel assembly, outfitting will be accomplished to the maximum extent possible. On-board outfitting is that required after erection of the individual units in the building basin. Figure 1-2 illustrates the flow of outfitting activities during these production stages.

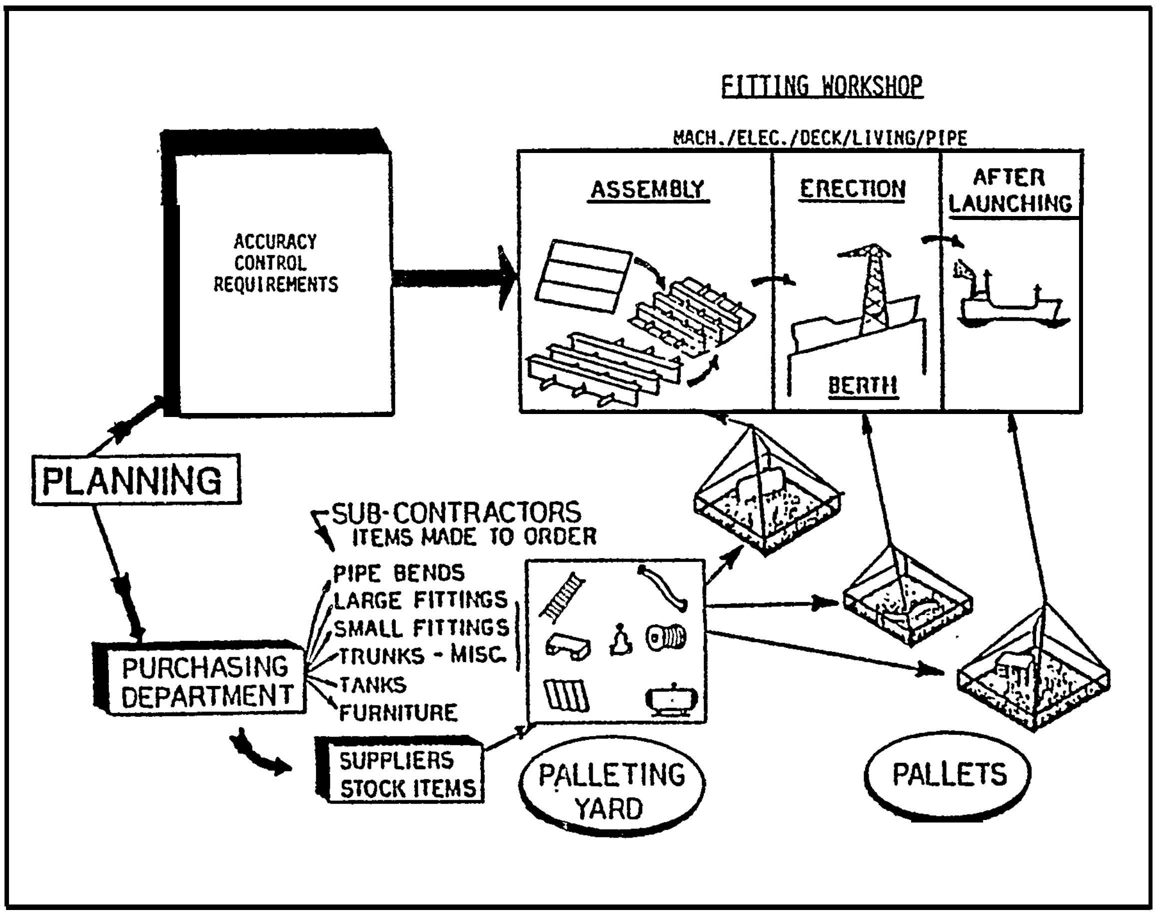


FIGURE 1-2

FLOW OF OUTFITTING ACTIVITIES

Throughout the ship construction process “mass production” techniques are utilized to obtain maximum production rates. All work is divided into discrete stages and precise processes within each stage; particular facilities are allocated to the performance of a particular operation; personnel are allocated to a single location and type of operation; and work is moved to the workers in each location. The objective throughout the production of one or several ships is to maintain the maximum flow of material through the production process in the minimum period of time. This provides a full and constant workload at each work station throughout ship construction.

Another basic objective of the system is to minimize the time consuming, expensive and relatively dangerous work during the erection stage. Therefore, accuracy of each component, sub-assembly and unit is stressed at each stage of production, and as much outfitting as possible is accomplished on the units prior to the start of erection to minimize on-board outfitting in the erected ship.

This highly effective system relies heavily on the thorough planning accomplished prior to the start of fabrication. This planning enables the total utilization of the facilities and personnel in a comprehensive and controlled manner throughout the ship construction process.

HULL CONSTRUCTION PLANNING

Hull construction planning follows a prescribed methodology which progressively breaks down and details successively lower levels of the hull until the parts and pieces at the lowest level of fabrication are completely defined. Essentially, the steps followed by shipyard engineers performing this breakdown are:

1. Unit division (i.e. dividing the ship into major units capable of being assembled, transpor te d and erected);

2. Assembly breakdown (i.e. defining the component sub-assemblies and detail parts which constitute each of the units);

3. Specifying the fabrication, sub-assembly and assembly methods to be used in the fabrication of the detail parts and the build-up of these parts into progressively larger and more complex assemblies.

This methodology is well known to U.S. industries. It is the system developed long ago for engineering drawing development and for assembly line production. This system was developed and established as the traditional production methodology for the U.S. aircraft industry during World War II. Its application to shipbuilding is also well known and understood although few shipyards employ it to the degree that the IHI yards do.

While this breakdown of the overall product and of the successive lower level “interim” products is being accomplished, a host of other planning activities are taking place. Facilities arrangements are confirmed; fabrication, sub-assembly assembly and erection processes are determined; material requisitions are determined and issued; and manpower and performance measurement requirements are established. Figure 1-3 depicts the flow of planning activities prior to the start of hull construction.

Preliminary Planning

Hull construction planning begins immediately upon completion of the Basic Design (accomplished by the Design Department in the Head Office of IHI in Tokyo). The Basic Design consists of: Unfaired

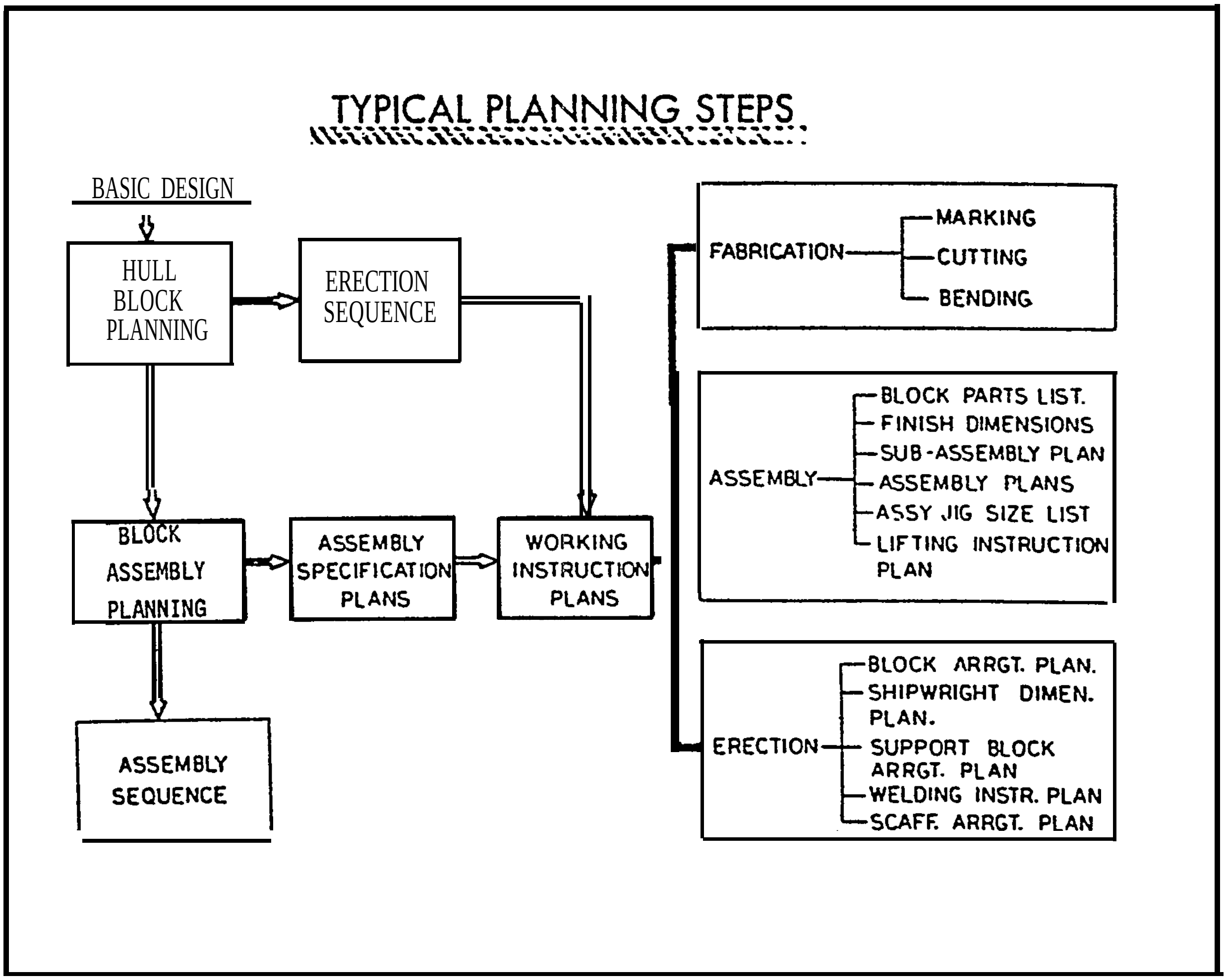


FIGURE 1-3

Ship's Lines, Midship Section, Construction Profile, General Arrangement and Machinery Arrangement drawings. On the basis of these plans, the shipyard Design Department undertakes the breakdown of the ship into "Blocks" or units. This activity is called "Hull Block Planning" and consists of dividing the ship into manageable units suitable for assembly and erection. (See Figure 1-4)

HULL BLOCK PLANNING

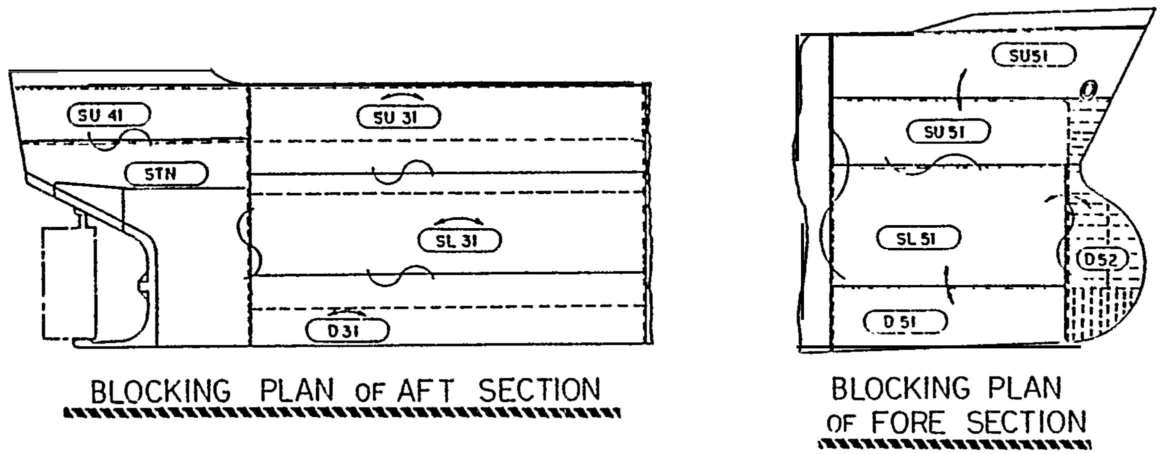


FIGURE 1-4

Unit Assembly Planning

After division of the ship into manageable units, typical common-shaped units are analytically disassembled in a progressive breakdown from the entire unit to the component sub-assemblies and then to the parts and pieces which constitute the sub-assemblies. All unique units are broken down in this manner. Figure 1-5 shows a typical example of such a breakdown.

These breakdowns serve several purposes in addition to showing the basic assembly sequence of each unit. A preliminary evaluation of the assembly sequence yields details concerned with the necessary

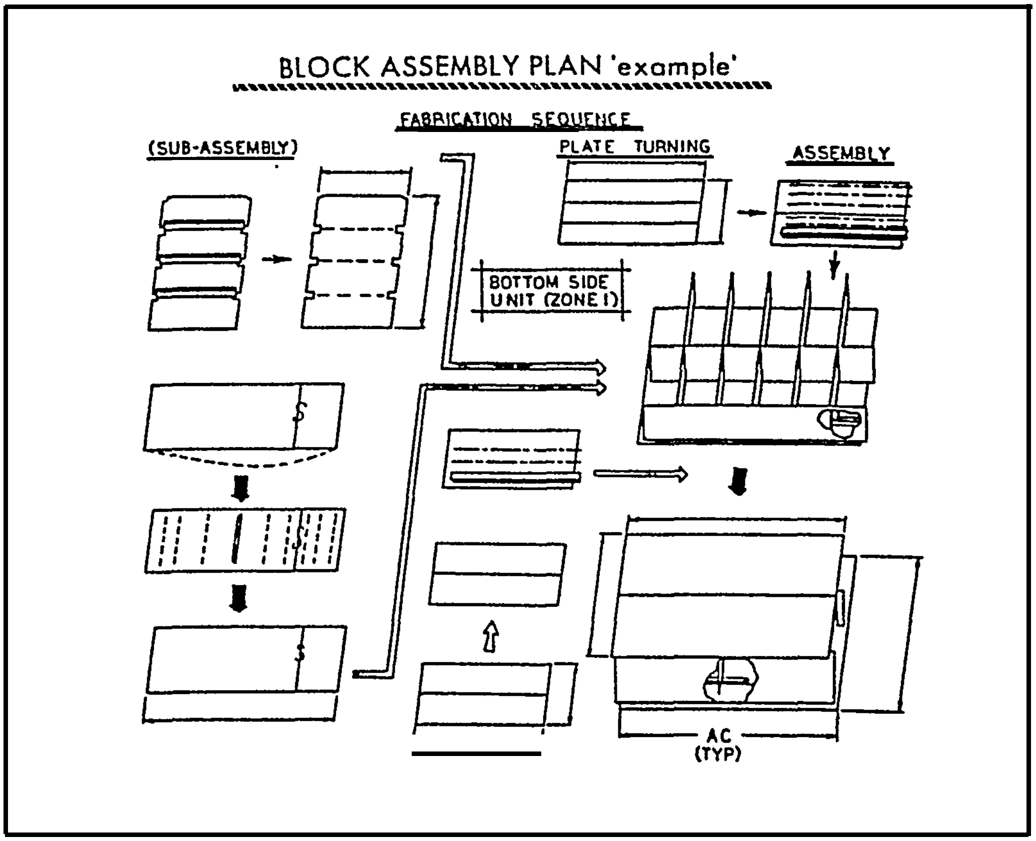


FIGURE 1-5

facilities and processes required for the assembly, e.g. , required fitting jigs, probable welding processes, required assembly area size and capacity. Further details are developed including: the classification of sub-assemblies and assemblies; reference level and line; length and types of welding joints; welding edge-preparation requirements; and requirements for added material for adjusting seam and butt lines.

All of this planning is considered "preliminary" information for the development of "detailed process planning" which is documented and disseminated as "Assembly Specification Plans" and "Working Instruction Plans".

Detailed Planning

During the preliminary planning stage, the Basic Design generated by the Head Office Design Department is refined and elaborated to the extent necessary to fix the Hull Blocking Plan. This design is referred to as the Functional Design and upon approval of the Hull Blocking Plan the Working Design is started.

At the start of the detailed planning stage, the Assembly Master Schedule is prepared from the Erection Master Schedule. On the basis of this schedule, the Material Requisition Schedule and Material Requisition Orders are prepared. Detailed Hull Construction Working Plans are also prepared by the Design Department defining the assembly units identified in the Hull Blocking Plan.

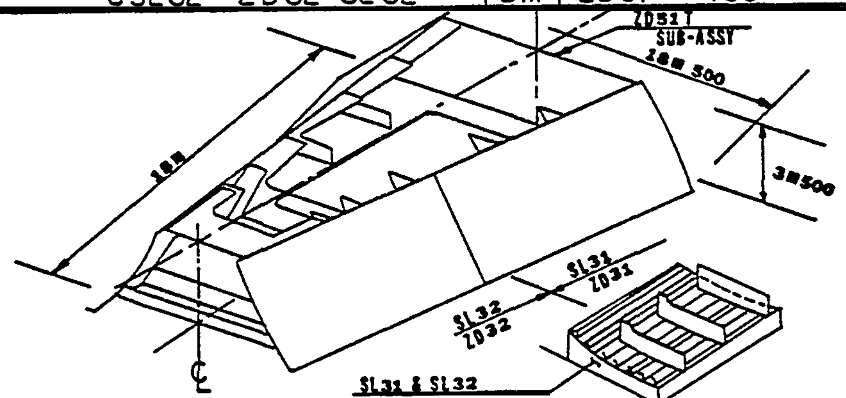
Based on these working plans and on the material requisition schedule and a Fabrication Lane Plan (which details the processing of plate steel through the fabrication shops), a Rough Cutting Plan is generated. This plan is made to assist in the preparation of Material Requisition Orders for steel plates to minimize the number of sizes, thickness and the total quantity of plates required. The purpose of the plan is to improve the usage and control of remnants and scraps; to determine the quantity of steel required each month; and to provide guidance for the preparation of the Cutting Plan for the workshop. The Material Requisition Orders are prepared on the basis of the information in this plan.

Assembly Specification Plans

Based on the information developed during the “preliminary process planning”, formal Assembly Specification Plans are developed. These plans detail the methods to be followed during fabrication, assembly and erection. This planning is accomplished by engineering personnel in the Design Department and by accuracy control engineers in the various workshops.

Detailed Assy. Specification Plan

Block	GSL31 ZD31-SL31 GSL32 ZD32-SL32	WT	TOTAL 58 TONS
		DM	ZD31 --- 403



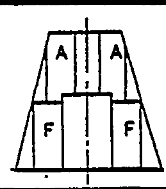
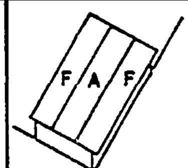
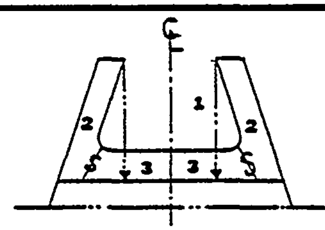
Steps	Assembly Process		ACCURACY CHECK Points
JIG SETTING	ZD31&ZD32 HORIZONTAL JIG	SL31 & SL32 FIXED POINT JIG	HORIZONTALLY
PLATE JOINING (ALL FAB. WELDING)			ASSY. REFERENCE LINE BEAM-- ℄ TRANS.-FLAT LONG GIR ZD32 BUTT ZD32 LENGTH BETWEEN BUTT LINE. & WEB
MARKING	ZD31 P/S ZD32 FINISH DIMEN. PLAN	SD31 & 32 BATTEN	
ASSEMBLY	ZD31-32 P/S EACH SL31-32 ASSY EACH SIDE PRE-ERECTION PRE-ERECTION FLAT BASE ZD31 FITTING PARTS ON FLAT BASE		
CONTROL INDEX	WL-AUTO 901M 288M		NONE
MAN-HOUR	ZD31-32 250 HRS.	SL31-32 420 HRS. GS31-32 250 HRS.	NONE

FIGURE 1-6

Work Instruction Plans

Working Instruction Plans represent the final planning step, and are derived from the functional and detailed design, Assembly Specification Plans, and the other data which have been progressively developed from the Basic Design for each unit. Working Instruction Plans provide detail working-level data for the fabrication, assembly and erection of each unit. These plans complete the development of data from the design level information to the working level details necessary for workshop execution.

Three Working Instruction Plans are prepared for each unit in the area of fabrication: Marking Plan, Cutting Plan and Bending Plan (often the Marking and Cutting Plans will be combined into a single plan).

In the area of assembly, six plans are prepared on each unit as follows:

- Unit Parts Lists
- Finishing Dimensions Plan
- Sub-assembly Plans
- Assembly Plans
- Assembly Jig Size Lists
- Lifting Instructions Plan

Working Instruction Plans originated for erection include:

- Unit Arrangements Plan
- Shipwright Dimensions Plan
- Support Block Arrangements Plan
- Welding Instruction Plan
- Scaffolding Arrangements Plan

These plans provide all necessary information at each production stage for the proper manufacture and handling of each unit. The basic objectives intended for these plans are: 1) to effect control of the total workload and the products as the work progresses through the various process lanes, sub-stages and stages of the production system; 2) to effect control of the great number of parts and pieces of material as they flow through the production processes; and 3) to provide explicit instructions to all levels of personnel concerned with the fabrication, assembly and erection of ship components.

OUTFIT PLANNING

In IHI outfit planning begins immediately upon receipt of the Basic Design and parallels hull construction planning in the development of the Hull Blocking Plan, Unit Assembly Plans and the functional and detailed design.

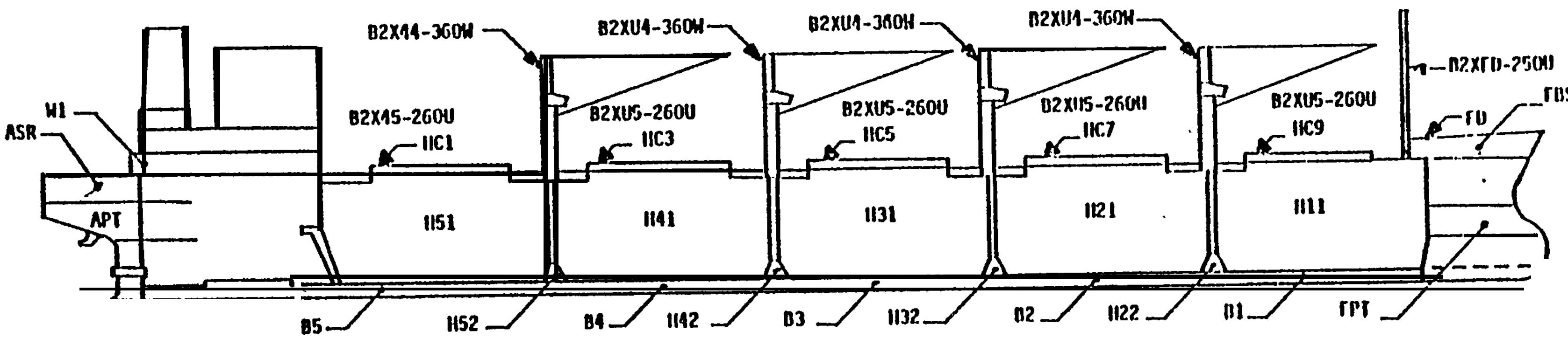
The IHI shipyards accomplish as much “pre-outfitting” of hull units as possible during the construction of these ship elements. This, of course, greatly reduces the amount of outfitting work that must be done during erection and after launch. The manhour and cost savings attributable to this approach are considerable and this approach is another factor in the high productivity achieved by these yards.

Pre-outfitting is a logical and highly effective method for reducing ship construction costs especially in light of the “modular” hull construction method used by IHI. The building of assembly units and the joining of units to form “grand units” provides an ideal condition for the installation of outfitting components and subassemblies at the various production stages of hull steel construction.

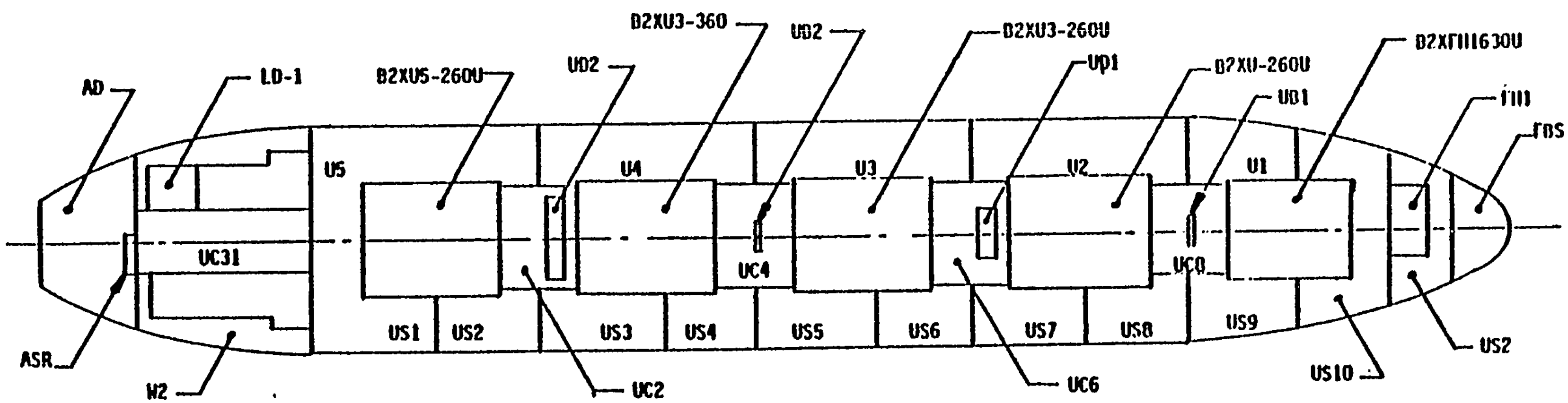
Naturally, the outfitting work performed during the build-up of hull units in the assembly areas is far less costly, less dangerous and is more accessible and amenable to down-hand welding processes. This type of outfitting also contributes to the IHI objective of shortening the work time in the building basin.

During the Detail Design stage, the data from the functional design is converted into working drawings of unit assemblies, sub-assemblies, detail parts and pieces, etc. Also, at the detail design stage an Outfitting Zone Plan is developed for the ship. This outfitting zone planning essentially sub-divides the major ship zones into smaller areas concerned with outfitting activities in the major ship sections, i.e. cargo hold, engine room, deck house, main deck, etc. An "Outfitting Zone" is simply a geographical area (3-dimensional) of the ship having no relation to aparticular system. Instead all systems within a given area are encompassed by the zone boundaries. An Outfitting Zone can represent a portion of a deck, a portion of several decks, one or more compartments, parts of adjacent compartments, etc. Figure 1-7 illustrates the Outfitting Zones identified for one type of ship.

With the identification and designation of Outfitting Zones detailed material lists are formulated together with piece drawings for the manufacture of pipe pieces, piping arrangements, and outfitting pieces and sub-assemblies. Specific material lists are prepared for the manufacture of pipe (Material List for Pipe - MLP) and for other outfitting components (Material List for Components - MLC). These material lists and the associated piece drawings are eventually scheduled for production through the yard pipe or fabrication shops.



FORE SECTION



UPPER DECK

FIGURE 1-7

OUTFITTING ZONES

In addition to the above, the Detail Design effort also produces composite drawings showing the layout of all outfitting material in specific “Work Zones” (a further breakdown of the outfitting zones into small packages of outfitting work). These composite drawings show the interrelationship of the many different systems integral to the individual work zones together with details of mounting and joining.

Upon completion of the composite drawings, the final stage of design, Work Instruction Design, is initiated. This design stage produces drawings of outfitting components which are to be installed at different production stages, e.g., sub-assembly, assembly, erection, after launch. Accompanying these drawings is another material list, the Material List for Fitting (MLF) which corresponds to the work to be accomplished at the production stage shown on the Work Instruction Drawing. This package of information describes the work to be done, the production stage at which it is to be done, and the list of materials which must be accumulated and present at the work site.

The Work Instruction Drawing, the associated MLF, the procured components and the manufactured components (i.e. by the yard) comprise a specific work package or “pallet” as it is defined by IHI. All information and all related material is collected at the proper work site, at the proper production work stage, and at the proper time interval to enable the outfitting of specific units or on-board the erected ship.

The “pallets” of information and material correspond to the “work zones” established for a given outfitting zone. These outfitting activities are rigorously scheduled to continuously parallel the hull construction sub-assembly, assembly and erection schedules.

ADDITIONAL PLANNING

The Hull Construction and Outfit planning discussed in the foregoing pages combine the aspects of design and production into a thoroughly defined set of working drawings and plans necessary for the manufacture of the hull units, the outfitting of those units and the erection and outfitting of the entire ship.

Throughout the above planning, a staff of Accuracy Control Engineers assists the planners and designers and formulates discrete accuracy control requirements for each unit, sub-assembly and piece part. These engineers develop detailed data concerning the vital dimensions and points of measurement to ensure that all manufactured components of the ship meet the highest accuracy standards possible. Additionally, these engineers develop a plan or scheme for providing added material at each stage of production to ensure that errors can be corrected without re-work of the part and to provide for neat cutting at the various sub-assembly, assembly or erection stages. Accuracy Control Engineers also define the base lines which must be used for unit alignment to keep maximum accuracy throughout the production, assembly and erection processes. The selection and application of process standards to the fabrication processes is also the responsibility of these engineers.

The objective of this accuracy planning is to effect the highest production efficiency by ensuring that each of the fabricated and assembled components meets prescribed standards and thereby requires no re-work as the material flows through the production process. This achievement of high accuracy reduces the amount of work required at the erection stage and ensures that the completed ship will meet or exceed all quality standards and will be in true alignment as required by design specifications.

Other plans are prepared by workshop staff personnel to detail the methods for facilitating work during the erection stage and during on-board outfitting. This planning is called “Field Planning” and consists of the following types of plans.

Plan for temporary holes (in the hull during erection)

Plan for ventilation and cooling of the hull on the ways

Plan for supply of electrical power and gas lines

Plan for stools arrangement on the ways

Plan for equipment access on-board and on working staging

Plan for standard shipwrighting techniques

Plan for maintaining shaft alignment considering the initial hogging of the aft and forward ship sections

Plan for tank arrangement and testing

Plan for final dimension check items

Plan for disposal of temporary pieces for construction

THE IHI SCHEDULING SYSTEM

The IHI scheduling system is a delineated hierarchy of schedules descending from the customer delivery requirement to the lowest working levels. The methods used by IHI in this scheduling system are not unique; however, some of the techniques are somewhat different in comparison to U.S. practice.

Basically, the system begins with the delivery schedule established by the Head Office. This schedule is reviewed in some detail by the

Production Control staff of the shipyard selected to build the ship and can be adjusted if found to be impracticable. If the yard can accommodate the ship in the time established by the Head Office, the Production Control group (in the shipyard's General Superintendent's office) formulates a Ship Construction Master Schedule which places the total building period into context with all other construction work in the yard. Placement of a new ship program in-to the Ship Construction Master Schedule is based on availability of facilities and personnel to accomplish the work in the desired time frame.

The Ship Construction Master Schedule becomes the guiding master schedule for the development of all lower schedules and is regarded as the one absolute and inflexible schedule thoroughout the building process.

Figure 1-8 presents the hierarchy of schedules which are developed from this primary master schedule. The next schedule prepared is the Major Milestone Schedule which defines the time period designated in the Ship Construction Master Schedule for construction of a particular ship or ships in terms of key events such as planning, fabrication start, keel laying, launch and delivery. Other key events that normally constrain the ship construction process, such as delivery of main engines or other long lead-time items that are procured from outside sources, may also be included. This schedule provides information for the construction of the Erection Master Schedule.

The Erection Master Schedule prescribes the sequence to be followed in the build-up of the ship in the building basin. The several major zones of the ship (i.e., mid-body, bow, stern and house) are separately scheduled and each of the units comprising these zones are scheduled

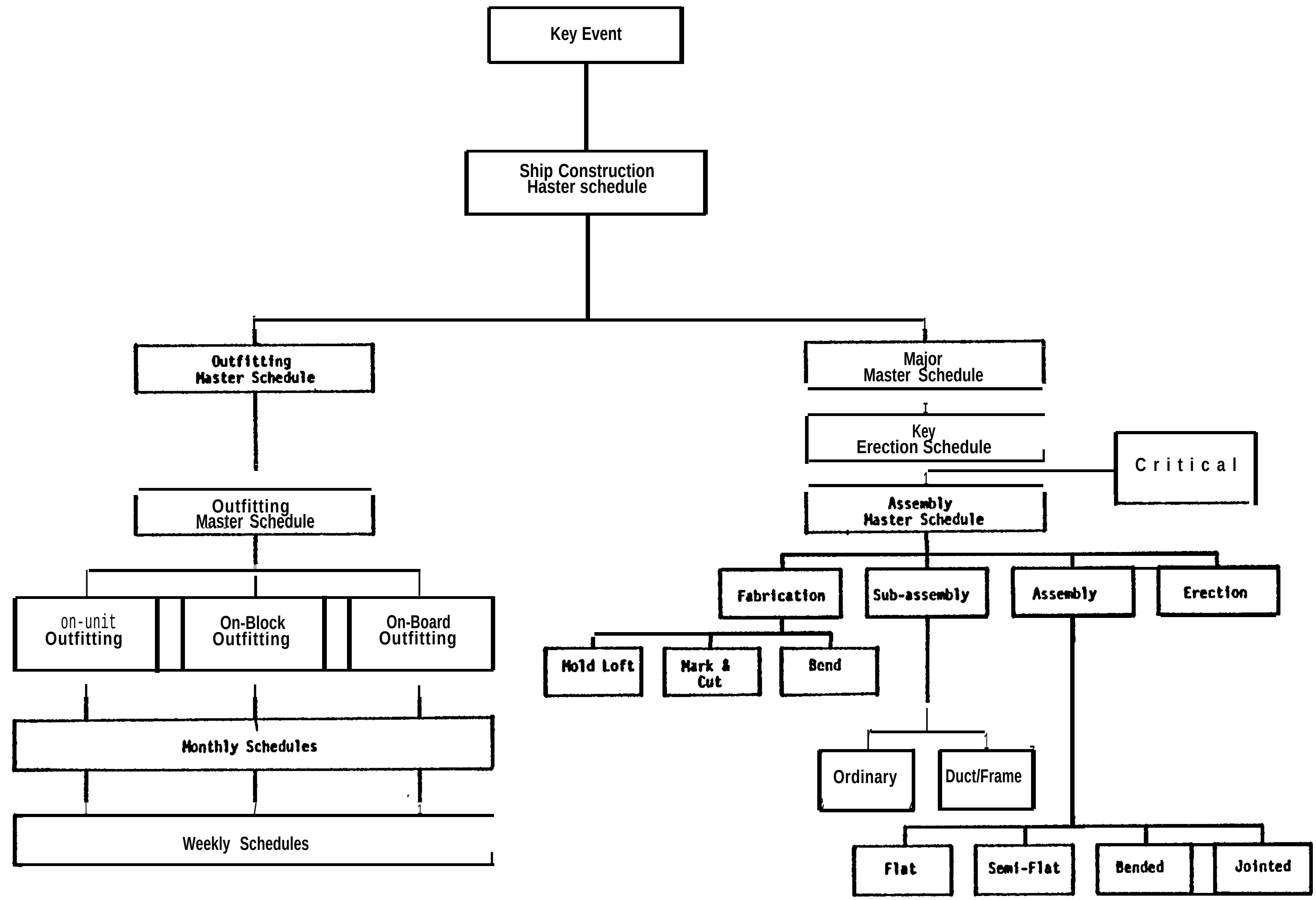


FIGURE 1-8

HIERARCHY OF SCHEDULES

individually for the precise time of landing in the basin. This erection schedule allows for the completion of all on-board outfitting work subsequent to the landing of the final unit on the erected ship. A precise set of standards is used to calculate the landing and joining of each unit to adjacent units already in the basin. These time standards dictate the amount of time required between each unit, and the schedule is developed as a series of “set backs” from the final unit in each zone.

Based on the mandatory erection time requirements for each unit, the Assembly Master Schedule is prepared. This Master Schedule establishes the periods for assembly of each unit sufficiently ahead of the erection schedule to permit unit outfitting and transportation to buffer storage or to the building basin platen areas.

From the Assembly Master Schedule detailed subordinate schedules for hull fabrication, sub-assembly, assembly and erection are prepared. These schedules are developed by the Production Planning and Engineering groups of the Hull Construction Workshop in conjunction with the applicable Section Managers and Foremen in the respective production stages and areas.

In the fabrication area specific sub-schedules are developed for the activities of the mold loft and for marking, cutting and bending of all materials for each of the hull units. In the sub-assembly areas, schedules are prepared for the common or ordinary sub-assemblies (such as webs) which are typical to many units and for more complex sub-assemblies containing ducting or major frame components.

Detailed assembly schedules are prepared for each hull unit.

Due to the different process lanes through which the flat versus curved units emerge, these schedules are prepared for each type of unit with somewhat different information presented thereon. Schedules are prepared for typical flat units (e.g. flat double bottom units), semi-flat units (e.g. curved shell and curved internal structure mounted on a flat panel such as the side double bottom units), bent or curved units (e.g. bow or stern units), and joined units (e.g. two units joined to allow the landing of a larger unit during erection).

The Erection sub-schedules detail the preparation, transport, buffer storage, and final erection of each unit in the building basin.

All of the above schedules are primarily concerned with the hull construction effort. In parallel with this effort, a series of outfitting schedules are prepared based on the Ship Construction Master Schedule and the hull construction schedules as they are developed for each stage of production.

After development of the Major Milestone Schedule, the Outfitting Milestone Schedule is prepared by the Production Planning and Engineering Group in the Fitting Workshop. This schedule expands the key milestones shown in the Major Milestone Schedule to include the periods where the fitting of the outfitting zones of the ship must begin and end. Other key events, which coincide with the receipt of major purchased equipment, are defined to indicate the completion of outfitting on critical sub-assemblies or units of the ship which will constrain the start of erection or the erection of specific units during the erection process.

The Outfitting Milestone Schedule provides the basis for development of the Outfitting Master Schedule. This schedule must of course coincide with the Assembly Master Schedule to allow proper time intervals for the installation of outfitting sub-assemblies and components during the build-up of each hull unit. Unit assembly instruction plans are carefully studied to determine the time requirements for outfitting, the outfitting area, and whether it would be more efficient to install individual components or outfitting sub-assemblies (e.g. a piping sub-assembly) into the unit.

Once the Outfitting Master Schedule has been developed, the detailed subordinate schedules are prepared. Individual schedules for the build-up of sub-assemblies of outfitting components (called on-unit outfitting), for the fitting of both these sub-assemblies and individual outfitting components in the hull units, and for installation of other sub-assemblies or components on-board the erected ship are prepared for each outfitting zone. Still more detailed schedules are then constructed for each group of fitting personnel based on the fitting tasks to be accomplished in order to execute the individual sub-schedules. These work schedules cover each month of the Outfitting Master Schedule and each week of each monthly schedule. These weekly schedules prescribe the task, the personnel and the time allowed for each outfitting activity each day.

In this descending hierarchy of schedules both the hull construction and the outfitting tasks are developed and sequenced to coincide with one another and with each higher level schedule. The Ship Construction Master Schedule usually contains only two weeks slack time which can be used to accommodate any unanticipated delays. This obviously requires careful and comprehensive schedule planning at each level of schedule development and a total commitment by all personnel to meet schedule dates once they are developed. The use of overtime is permitted in order to maintain schedule position but unless overtime is purposely included in the schedules (by top-management decision) the use of overtime is restricted to the most dire circumstances.

MANPOWER PLANNING

Manpower planning in IHI is a precise method of applying personnel resources to each task of the well defined production process. The planning accomplished for hull construction and outfitting and the exact scheduling of these activities provides the framework for the application of manpower in discrete stages, sub-stages and time periods.

The entire production process is organized around the "process lanes" system. As previously discussed, this system allocates specific types of work to particular work stations established in a fixed location within one of several process lanes. In Hull Construction these work stations are related to lofting, marking, cutting, bending, sub-assembly, assembly and erection. The activities of each of these work stations is defined in great detail in the plans prepared prior to the start of fabrication, and further delineated in the detailed schedules discussed in the previous section. The organization of the basic production system and this highly refined planning and scheduling allows the application of personnel to small increments of work at fixed times throughout the hull production process.

In outfitting the same basic methodology is applied although the locations and mix of personnel vary according to the type of outfitting being accomplished. Also, the fabrication of pipe is a discrete planning and scheduling effort of its own and the application of manpower is determined separately from that of hull construction and outfitting.

The computation of manpower in each of these major areas of hull construction, outfitting and pipe fabrication is based to a large extent on the historical data accumulated by the various yards from the prior construction of similar ships. This historical data has cataloged production rates per manhour in terms of weight of steel, weld metal deposited, cutting length, outfitting component weight and manhours required for sub-assembly or installation, painting and pipe fabrication. The application of these data to the same type of operations ship after ship is a routine and accurate process.

The budget planning process in IHI is not unlike that utilized in U.S. yards, although the participation of the workshops planning staffs is a unique aspect and indicates that workshop managers participate more fully in the establishment of their budgets than their U.S. counterparts.

Essentially, the overall budget is established by the IHI Head Office and refined by the shipyard General Manager into working budgets for each department in each workshop. This refinement of the overall budget is accomplished both by the Production Control Department which is staff to the General Manager, and by the Production workshops. The estimate generated by Production Control is in more general terms and is based primarily on historical data collected from previous ship construction programs. Production department estimates are in precise terms of numbers of welding and fitting manhours required per day/week/month.

Subsequent to the initial estimation of manhours by Production

Control and the production shops, a Budget Meeting is held and a decision as to the operating budget is made by the General Manager. This operating budget is then issued by Production Control to the various cost centers in the yard. No adjustment of the budget is made until one or two months before ship delivery. This adjustment is made on the basis of accumulated manhour expenditures at another meeting of Production Control, the affected shop(s), and the General Manager. Figure 1-9 shows this budgeting process.

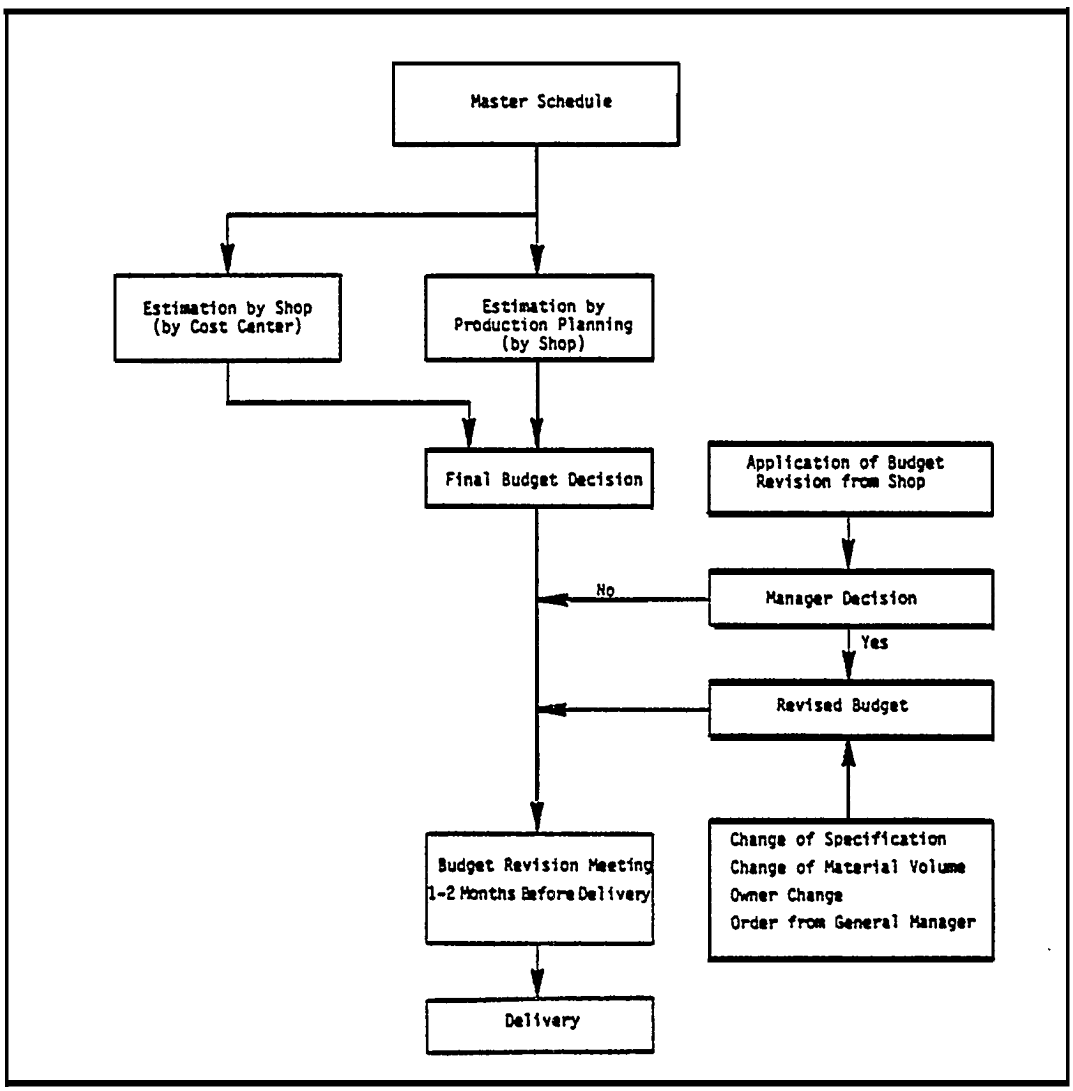


FIGURE 1-9 BUDGET PROCESS

The entire manpower planning cycle extends from the overall planning accomplished to establish the shipyard and department budgets to the manhour plans of the individual foremen of each production area. Manpower planning at the working levels consists of the identification and scheduling of the work groups allocated either to the hull construction work stations or to the fitting tasks in the outfitting schedule. Manhours are continually weighed against the actual manhours used on previous ships and by the various factors of manhours/ton, manhours per length of weld deposited, cut lengths, outfittings weight, cable lengths, etc. This manpower planning, when combined with the production planning and scheduling forms a complete framework of data for the performance of all work in each area of production.

PRODUCTION CONTROL

Production Control in the IHI yards happens as a natural consequence of the production planning and scheduling system. The organization of the hull construction and outfitting shops and activities, the detailed planning accomplished for each of these activities and the use of working level schedules for small groups of personnel allows close monitoring and control of each step of the production process.

Basically, three organizations are concerned with production control: the Production Control Department and the Production Planning and Engineering groups for the Hull Construction Workshop and the Fitting Workshop respectively. This de-centralized control parallels the de-centralization which characterizes the planning and scheduling activities. The Production Control Department is primarily concerned with the overall yard aspects while the Production Planning and Engineering groups are concerned with the detail control of the workshop activities.

The activities of these three groups start from the overall yard planning and scheduling and descend to the levels of the individual work stations. However, once production has begun the daily inputs from the working levels are coalesced into the control information required to judge the status of the total program. In the planning phase the production control system works from the top down, in the production phase the system works from the bottom up.

Production Control Department

The Production Control Department is responsible to the shipyard General Manager for the planning and scheduling of yard facilities and manpower for all ships and other types of construction in process and backlogged. This department prepares the Ship Construction Master Schedule; accomplishes the planning of production functions in terms of weight, cutting length, welding length, outfitting weight, cable length, etc.; prepares the overall yard manpower plans; prepares the overall yard work load schedule; and prepares the manhour efficiency control curves used to monitor shipyard performance.

This top-level planning and control is translated to successively lower levels of the organization until each organization (i.e., workshop, section, group) and each production stage (i.e., fabrication, assembly, erection and outfitting) is fully detailed by planning, schedules and performance control data.

Because of the thoroughness of the planning and scheduling, usually only minor changes to the top-level plans and schedules are required. If changes are required, they are generally accomplished at the working levels such that the top-level plans are not affected. Although the overall status of each program is closely monitored by the Production Control Department, the majority of the actual production control activity is performed by the workshop Production Planning and Engineering groups.

Production Planning and Engineering Groups

These groups, called the workshop staff groups, attend to a multitude of planning, scheduling, coordination and control functions. As previously mentioned, these groups are responsible for working with design engineers in formulating the various plans and schedules to be used throughout the production process. They also interface closely with the foremen, Section Managers and the Production Control Department in the preparation and updating of man-loading and performance control charts and graphs.

Once the top-level shipyard planning is accomplished by the Production Control Department, the workshop staff groups begin the development of the detailed plans and schedules for the actual operations of the various hull and outfitting groups. The wealth of planning data developed during the detail design process together with the master schedules form the basis for the preparation of these detailed shop and group plans and schedules.

Production Control of the various activities occurring in the Hull Construction Workshop involves the planning and scheduling and subsequent monitoring and control of the manpower, processes and methods utilized in these activities. The hull construction process, for purposes of production control, is divided into the following areas: total hull, lofting, fabrication, sub-assembly, assembly and erection. Within each of these areas several different means are established to monitor production performance. Table T-1 shows the various control graphs prepared for each area.

TABLE T-1

HULL CONSTRUCTION CONTROL GRAPHS

AREA	TYPE OF GRAPH	BASE
TOTAL HULL	Advance Curve - Wgt.	Day
	M/H	Erected Wgt.
	M/H	DM
LOFTING	Engr. Dwgs Vs. Loft Dwgs.	Day
	M/H Vs. Plan	Day
FABRICATION	Steel Wgt. Vs. Plan	Day
	M/H per Steel Wgt.	Day
UB-ASSEMBLY	M/H	Wgt.
	M/H	DM
ASSEMBLY (Ea. Area)	M/H Vs. Wgt.	Day
	M/H Vs. DM	Day
ASSEMBLY (Total)	M/H	Wgt .
	M/H	DM
ASSEMBLY WELDER	M/H	DM
ASSEMBLY FITTER	M/H	DM
ERECTION	Advance Curve - M/H	Day
	Erected Wgt.	Day
	M/H	Wgt.
	M/H	Bn.L
	Hull Fitter M/H	Bn.L
	Welder M/H	Bn.L

Legend:
DM - Deposit Meter
M/H - Manhour
Wgt. - Weight (ton of steel)
Bn.L - Weld length x difficulty coefficient

As mentioned previously, outfitting activities parallel the hull construction activities of sub-assembly, assembly and erection. With the exception of pipe fabrication and painting, these activities involve several or all of the fitting groups in the outfitting organization.

Although the outfitting organization is structured essentially around the outfitting zones of the ship (i.e. Interior or Accommodations Fitting group, Deck Fitting, No. 1 and No. 2 Machinery Fitting, and Electric Fitting group) the manloading and scheduling of the outfitting tasks is oriented toward On-unit (i.e. sub-assembly of outfitting components), On-block and On-board activities. Hence, the outfitting tasks require a blending of the skills of each of the organizational groups into the type of work groups required for a given task. Also, since the outfitting tasks are not of a repetitive nature (such as those in hull construction) and since these tasks are performed in a number of different locations, a distinctly different type of manhour and schedule control is required.

In outfitting there is far more reliance on the use of the monthly and weekly schedules than on performance control charts or graphs although such control graphs are used to measure the progress of each group.

As discussed above, Production Control evolves from the top-level planning, scheduling and control graphs to the successively lower levels of production. In outfitting this top-level planning and control is manifested by the Shipbuilding Master Schedule, the Outfitting Milestone Schedule, the Outfitting Master Schedule and the corresponding shipyard and Outfitting Section control charts. Beneath this level production control charts are prepared to reflect progress of each work group during On-unit, On-block and On-board outfitting. Figure 1-10 illustrates this descending hierarchy of controls and the correlation between these control charts and the related schedules.

LIVINGSTON APPLICATION OF IHI TECHNOLOGY

During the course of the Technology Transfer Program, Livingston has adopted many of the IHI techniques of production planning and control. This has entailed a detailed study of the IHI system and a careful evaluation of the parts of the system applicable to LSCo.

As a result of the LSCo. studies, the decision was made to convert the Livingston production system to an approximation of the IHI system over a period of time and to initiate changes to the Livingston scheduling system which would lead eventually to an IHI-type system. All of the planning data originated for the first of the modified Future 32 bulk carriers being built by Livingston was converted piece-by-piece to the IHI methods.

In early 1980 Livingston began to modify its production system to one using the concept of the “Process Lanes” system of IHI. To avoid confusion during this period of re-organization the term “Gate System” was adopted to describe the production system of LSCo. Essentially, the system comprises a series of “gates” which are equivalent to the IHI sub-stages and stages (i.e., plate cleaning, marking, cutting, bending, sub-assembly, assembly, erection and the several outfitting stages of sub-assembly of outfitting components, installation on assembly units, and installation on-board the erected ship). Each of

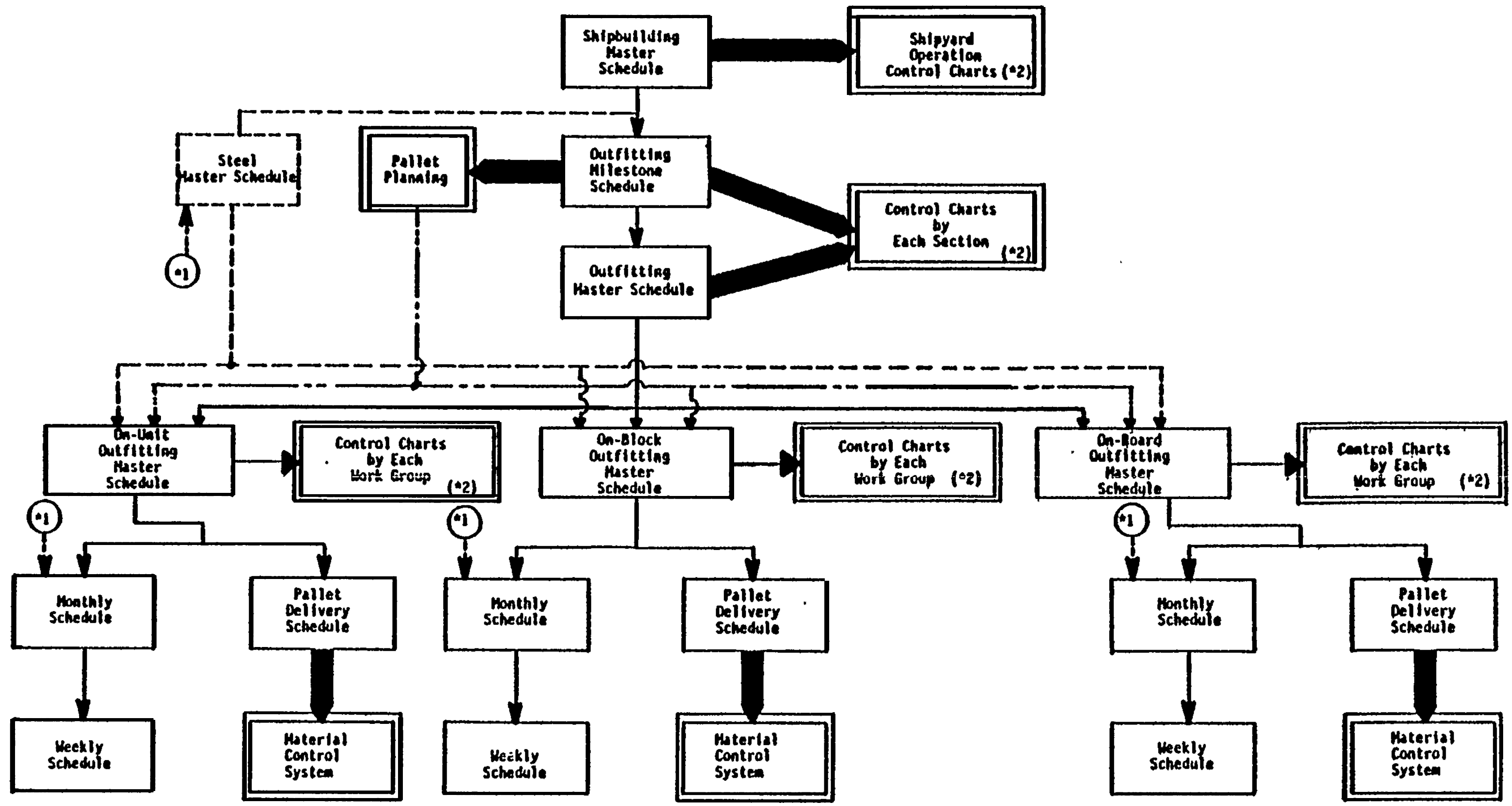


FIGURE 1-10

OUTFITTING SCHEDULING SYSTEM (IHI)

these gates has an assistant foreman or foreman permanently assigned and a number of worker personnel. The gates process steel according to detail gate schedules to support the assembly, outfitting and erection master schedules.

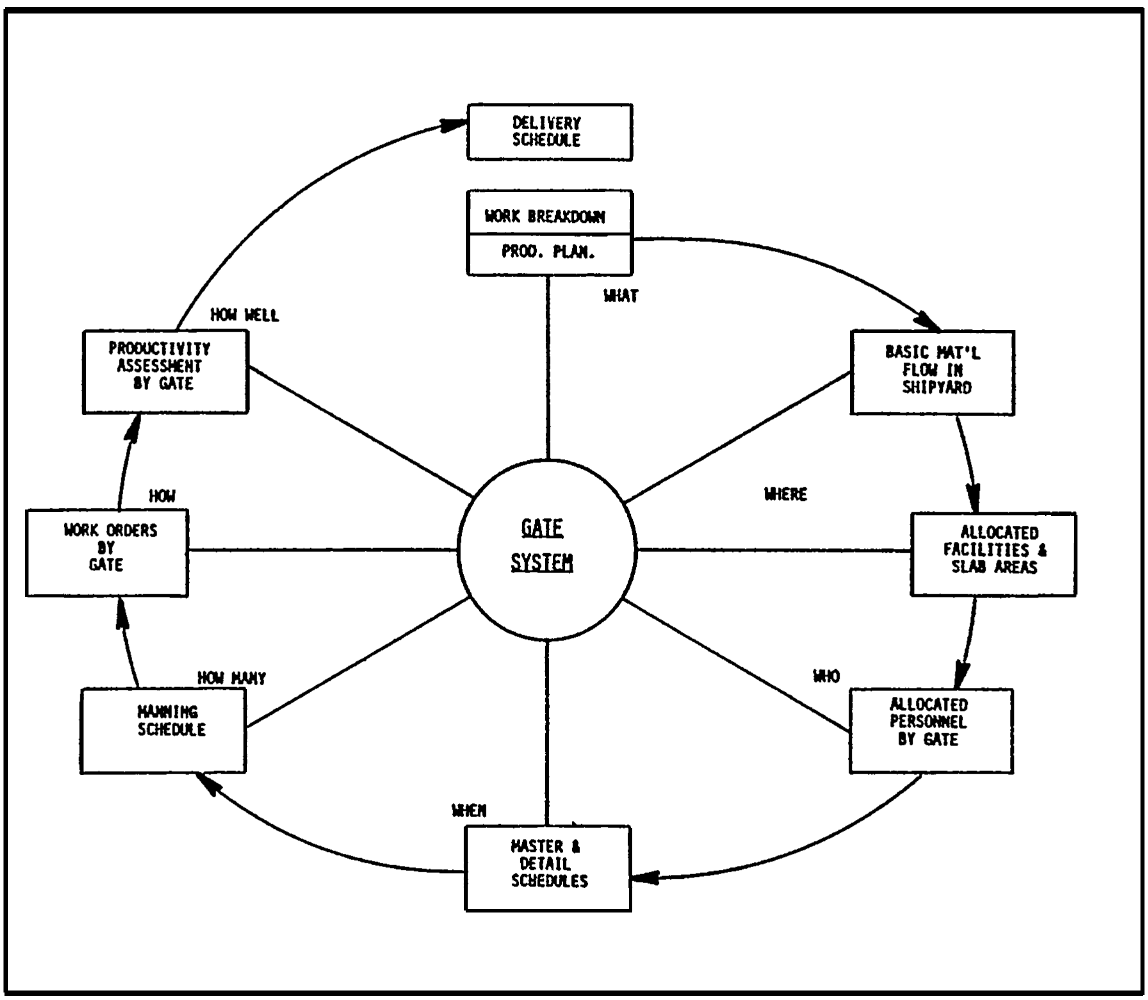


FIGURE 1-11

GATE SYSTEM

With the adaptation of the “Gate System” Livingston is fully committed to the application of the IHI production planning and control techniques. These techniques have necessarily been modified to fit the facilities, capabilities and personnel organization of Levingston. Many of the peripheral aspects of the system, such as Accuracy Control, decentralized planning and production control, the decentralized organization of work groups and staff groups, and total communication of planning and scheduling information to the work positions, have not yet been addressed in their fullest degree for application.

Figure 1-12 presents a diagram of the current Livingston planning, scheduling and manning control system currently in operation.

APPLICATION TO U.S. SHIPBUILDING

The application of the IHI Planning and Production Control system to typical U.S. shipyards is entirely practicable and desirable. The institution of this system, however, requires major modification not only to the planning and scheduling practices of the typical U.S. yard but also to the production system itself.

As explained previously, the heart of the Japanese system is the organization of the production flow through “Process Lanes”. These lanes are the essential ingredient to the establishment of the planning and production control methods utilized by IHI. This may entail some radical changes in yards which have not been structured around an “interim product” or “module” type of ship construction.

The institution of the IHI system requires a thoroughly developed plan which must be executed at the beginning of each new contract. Since the majority of planning for production needs to be accomplished prior to the start of fabrication, this planning should be incorporated

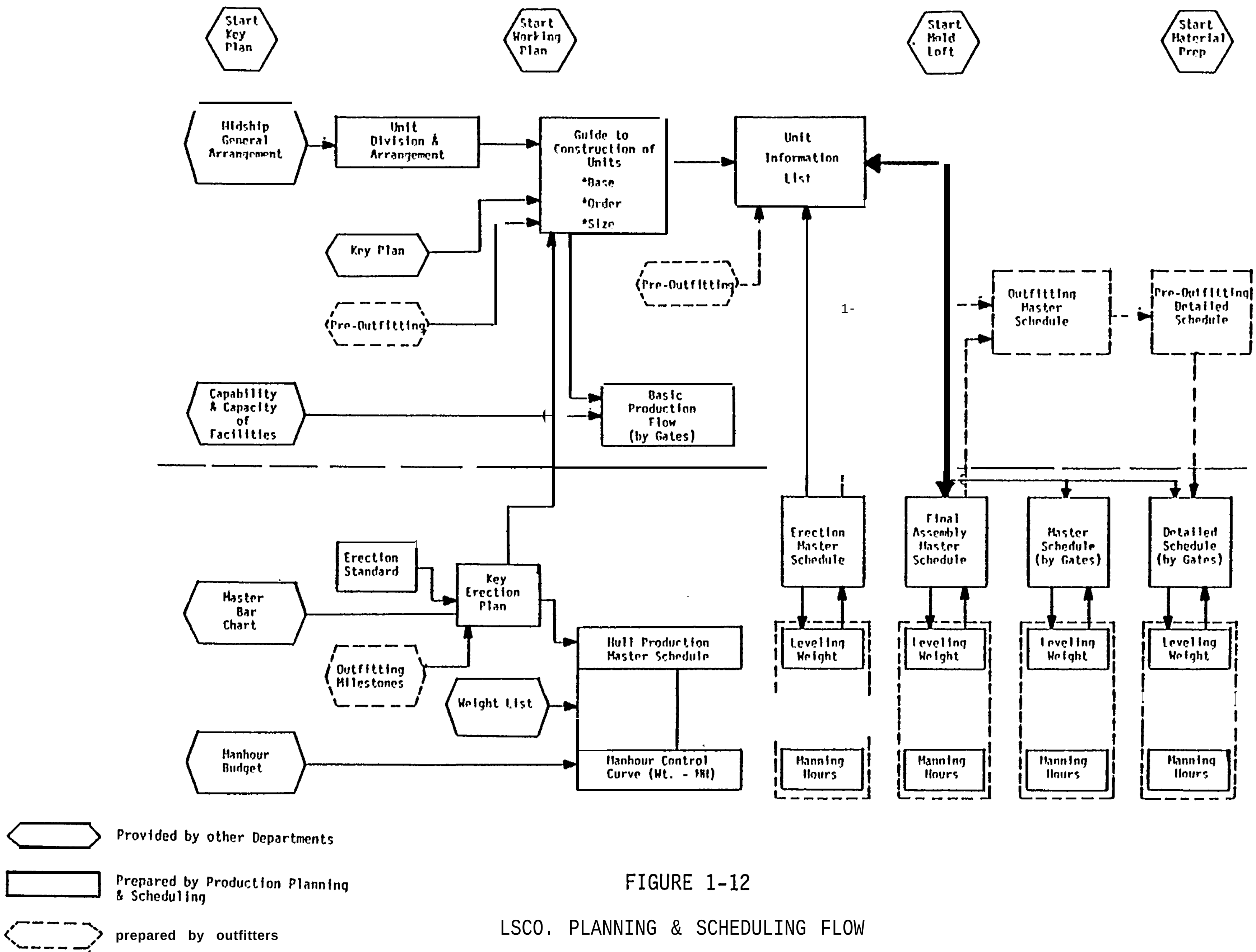


FIGURE 1-12

LSCO. PLANNING & SCHEDULING FLOW

into the design effort and, in fact, be a part of the design development. Naturally, in order for this planning to be meaningful, the production system, both hull construction and outfitting, must be thoroughly developed and in place to support a rapid and optimized production schedule once fabrication has begun.

Several major obstacles present themselves in the institution of this type of planning and control system. The most formidable, of course, is the realignment of the production system into a "Process Lanes" type of organization. The second is the development of the planning and production control system organized around the new production structure. Additionally, restraining of personnel, material flow/handling/control, pre-outfitting, and the application of accuracy control and quality control methods to the new system must all be investigated to ensure that all aspects are integrated to form a precise composite that does indeed benefit and not degrade production rates.

Livingston's study of the IHI system has derived one over-riding axiom for the application of IHI practices, that is: the IHI ship construction system is a well developed and highly integrated whole, pieces of which can be adopted for use in U.S. yards and can be effective, but only through the adoption of the total system can any great increase in productivity be effected. This applies especially to the planning and production control system. Only through the adoption of the IHI production system does the direct application of the IHI planning and control system have meaning and, similarly, only through the adoption of the production system does the IHI pre-outfitting methodology have significant benefit. Each piece of the planning and production system is dependent upon every other piece. One piece cannot stand alone.

Currently, Livingston has implemented only a portion of the planning methodology used by IHI. Table T-2 shows the planning techniques presently utilized by LSCo. versus those of IHI. The planning shown in the table that has not been adopted by LSCo. is of course, accomplished in one form or another, but is generally less formal and less discretely identified than that of IHI.

TABLE T-2

PLANNING AND CONTROL TECHNIQUES ADOPTED BY LIVINGSTON

IHI Planning & Control Technique	Adopted by LSCo.
Hull Block Planning	Yes
Block Assembly Planning	Yes
Assembly Specification Plans	Not Completely
Work Instruction Plans	No
Marking Plan	
Cutting Plan	
Bending Plan	
Block Parts Lists	
Finishing Dimensions Plan	
Sub-assembly Plans	
Assembly Plans	
Assembly Jig Size Lists	
Lifting Instructions Plan	
Block Arrangements Plan	
Shipwright Dimensions Plan	
Support Block Arrangements Plan	
Welding Instruction Plan	
Scaffolding Arrangements Plan	
Outfit Planning	
Zone Planning	Yes
Material Ordering Zones	No
Work Zones	Yes
MLS - MLP - MLC -MLF	Mat'1 Information List

The IHI Planning and Production Control System is a comprehensive and effective system in the IHI shipyards, but because of its total orientation toward the production system, methods, processes and techniques of the IHI yards, its application to U.S. yards is dependent on the willingness of U.S. yards to change their production methodology. There is little doubt that should a U.S. yard successfully replicate the IHI planning and production system that such a system would have a significant effect on productivity although, because of the cultural differences between the two countries, U.S. yards may never achieve the productivity levels experienced by Japan. Many more aspects of productivity, besides those of planning and the production system, will influence the ultimate productivity equation and, although this area of production is by far the most significant in terms of technology that can be adopted by the U.S., it is entirely possible that the areas of non-technological application (such as personnel relations) can produce an influence of equal proportion. In any case, U.S. yards cannot help but derive benefit from the study of this technological area.